UHF Electrically Large Near-Field RFID Reader Antenna Using Segmented Loop Unit

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***Abstract-* An ultra high frequency (UHF) electrically large near-field RFID reader antenna using segmented loop unit is proposed to enlarge the interrogation zone. The proposed antenna is composed of two segmented loops with one common side and a feeding network. Each loop has a uniform and single direction flowing current itself. By providing reverse-direction flowing current to the two segmented loops, the strong and uniform magnetic field distribution over a large interrogation zone can be achieved.**

I. Introduction

Ultra-high frequency (UHF) near-field radio frequency identification (RFID) receives a lot of attention due to its promising opportunities in item-level RFID applications, such as sensitive products tracking, pharmaceutical logistics, transport, medical products, and bio-sensing applications [1-2]. The top challenge of the UHF near-field RFID reader antenna is to generate a strong and uniform magnetic field distribution over an electrically large interrogation zone area.

In most near-field RFID applications, the inductive coupling between the reader antennas and tags is preferred because it is capable of operating in close proximity to metals and liquids [3]. Some designs have been reported to address the design of electrically large single-loop antennas for UHF near-field RFID readers. The key design principle of such works is to ensure that the current is of equal magnitude and in-phase along the loop. Dobkin et al. presented a segmented loop antenna loaded with lumped capacitors [4]. Oliver conceptually proposed three broken-loop antenna patents using triple lines, double lines and single lines [5]. Qing et al. proposed the segmented loops using distributed capacitors [6] or dash lines [7]. The reported single segmented loop antennas are with a limited interrogation zone, the perimeter of the interrogation zone is less than 2λ (λ is the operating wavelength at 915 MHz in free space).

In this paper, the segmented loop with a side length of about 0.5λ is selected as a unit to configure an UHF near-field antenna with an interrogation zone of double area of that of the segmented loop unit and the perimeter of the interrogation zone achieves 2.8λ. Comparison between the proposed antenna and the single-loop antenna with the same area is provided. The procedure to implement this antenna prototype is addressed with a practical guideline.

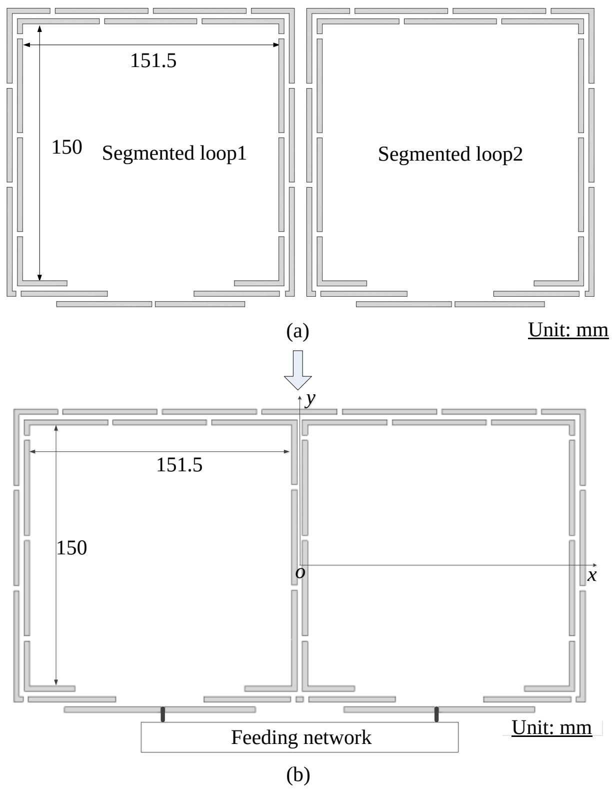


Fig. 1. Configuration of (a) two separated segmented loop units with the size; (b) the proposed electrically large antenna.

II. The Proposed Near-Field Antenna

A. Antenna configuration

Fig. 1(a) shows the two separated segmented loops. The segmented loop, which is similar to that in Ref. 7, can generate the strong and uniform magnetic field distribution because the current along the segmented loop is in-phase. To get the strong and uniform magnetic field distribution over a larger interrogation zone, the segmented loop is set as a unit to combine a new UHF near-field antenna as shown in Fig. 1(b), where the two segmented loop units sharing a common segmented side. A Cartesian coordinate system is built, and the origin of the coordinate system is the center between the two loops at the upper surface of the substrate. The internal area of the proposed antenna is indicated as the interrogation zone with

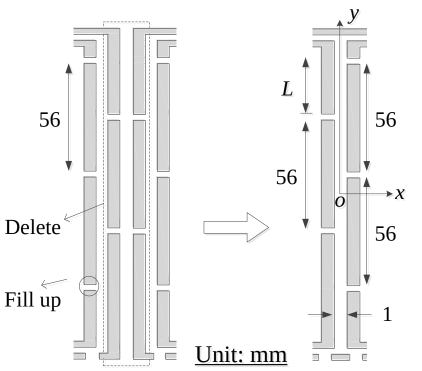


Fig. 2. Change from two separated segmented sides into one common segmented side of the proposed antenna.

a perimeter of 910 mm or about 2.8 λ at 915 MHz.

B. Design procedure

The design procedure of the proposed antenna is summarized in the following two steps.

Step 1 Design a segmented loop as the unit

The first is to configure a segmented loop with in-phase current along the loop, as shown in Fig. 1(a). The methodology to configure the segmented loop is similar to that in Ref. 7.

Step 2 Configure the proposed antenna

The second is to configure the electrically large antenna by combining the two separated segmented loop units. The key is to configure the common side. The other three sides of each segmented loop will not be changed. Fig. 2 exhibits how to change the two separated segmented lines into the common segmented side of the proposed antenna.

As shown in Fig. 2(a), to configure the common segmented side, the separated segmented lines of the two segmented loops are moved close to each other. Then the two segmented lines in the middle are deleted, and the lower gap on the left side segmented line is filled up to get the common side.

To compensate the central area of the proposed antenna, there should be a strong current along the common side. Therefore, the two ports of the feeding network should be 180^o out-of-phase so that the currents along the two loops are superposed each other when flowing into the common side.

However, the length L in Fig.2 (b) should be optimized to keep the magnetic field distribution of the proposed antenna is the best. Fig. 3 shows magnetic field distribution of the electrically large antenna at 915 MHz along y = 45 mm when L is changed. As shown in Fig. 3, the electrically large antenna has the strongest magnetic field distribution ($|H_z|$) when L is 28 mm, which is exactly half of the distance (56 mm) of the segmented line sections between the two gaps. The length of 56 mm is also the main length of the single segmented loop unit to keep the current along the unit in-phase at 915 MHz.

C. Results

The antenna is optimized and prototyped with an overall size of 318 mm × 182 mm × 0.5 mm and offers an interrogation

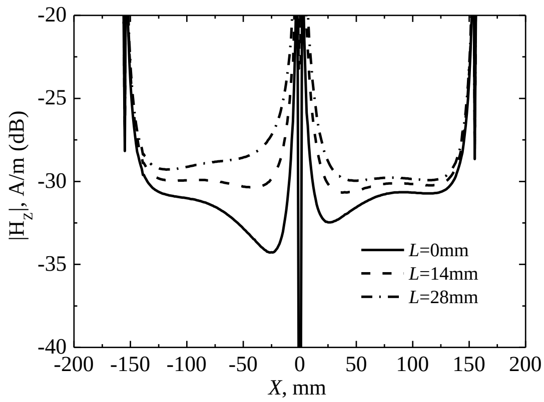


Fig. 3. The simulated magnetic field distributions of the proposed antenna with two segmented loop units with varying L at 915 MHz (z = 0.5 mm) along y = 45 mm.

Fig. 4. Photo of the antenna prototype using the FR4 substrate.

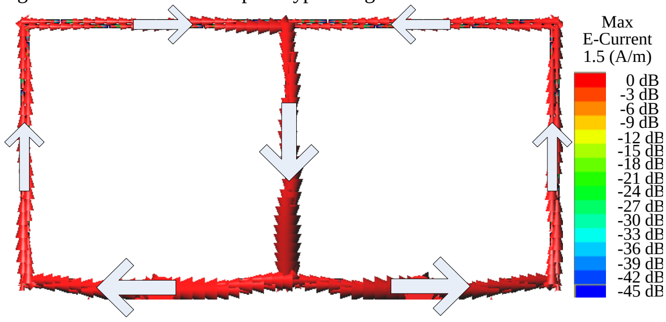


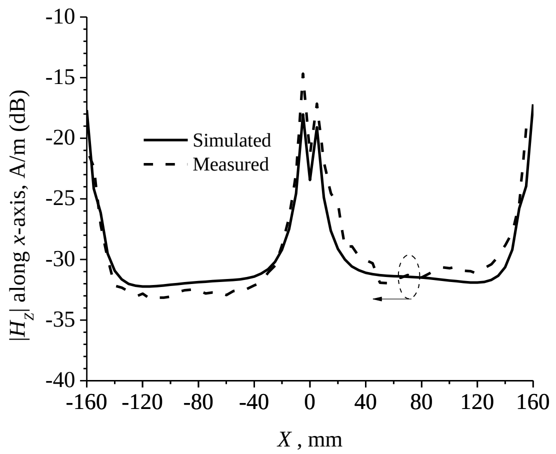
Fig. 5. Simulated current distribution of the proposed antenna at 915MHz at 915MHz

zone of 308 mm × 150 mm. The antenna prototype fabricated onto an FR4 PCB is shown in Fig. 4, where the feeding network is realized by the double-sided parallel-strip line printed onto the opposite sides of the substrate.

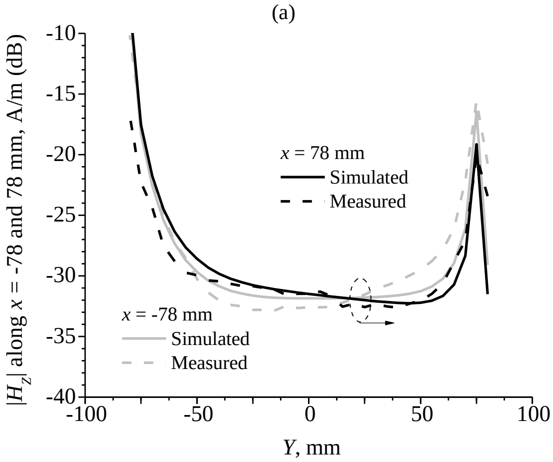
Current and magnetic field distribution

Fig. 5 exhibits the simulated current distribution of the proposed antenna operating at 915 MHz. From Fig. 5, it can be seen that the currents along each loop are still in-phase, but the two currents are reverse-direction, one is clockwise, and the other is counter clockwise. Since the currents along the two loops are superposed each other when the currents from the two loops flow into the common side, the current along the common side is stronger than those currents along other sides except the sides with excited line sections

Fig. 6 compares the simulated and measured magnetic field distribution at 915 MHz. The measurement method is the same as that in Ref. 8. The near-field magnetic field probe was placed on the surface of the antenna prototype and the interval of detection points is 5mm.



(a)



(b)

Fig.6. Simulated and measured magnetic field distribution of the proposed antenna prototype at 915 MHz (z = 0.5 mm) along (a) x-axis and (b) x = -78 and 78 mm.

Impedance matching

The measured return loss of the proposed antenna was carried out using Agilent E5230A vector network analyzer. Fig. 7 shows the simulated and measured $|S_{11}|$ of the proposed antenna. From 790 to 1040 MHz, the $|S_{11}|$ is smaller than -10 dB. The slight shift of $|S_{11}|$ is produced by the fabrication error of the gaps and the thickness of the substrate.

Reading range

To further verify the performance of the proposed antenna, the antenna prototype was used as the reader antenna in the UHF near-field RFID system to detect UHF near-field tags (J12, 15 × 8mm^2). The measured reading rate against the reading range is exhibited in Fig. 8. The proposed antenna offers the bi-directional detection along the ±z axis. A 100% reading rate is achieved within a maximum distance of 13.5 mm, while the reading rate of the single segmented loop antenna with the identical size is greatly reduced at the same distance.

III. CONCLUSION

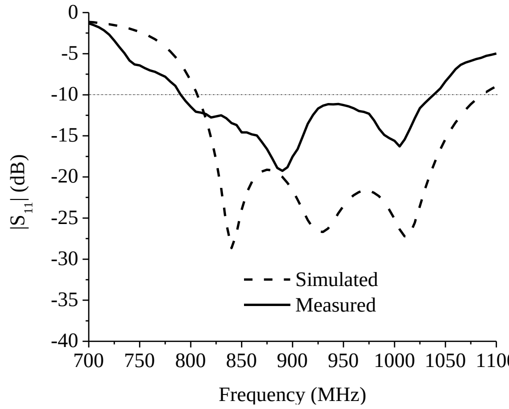


Fig. 7. Simulated and measured $|S_{11}|$ of the proposed antenna prototype.

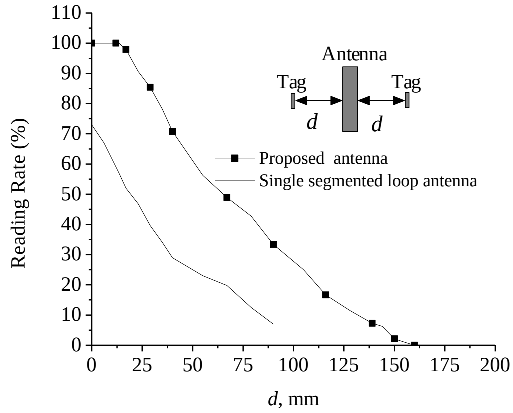


Fig. 8. Measured reading rate against reading range of the proposed antenna prototype.

Designing electrically-large UHF near-field RFID reader antennas is a big challenge, especially when the perimeter of interrogation zone reaches three wavelengths or more. The proposed antenna using segmented loop unit can produce strong and uniform magnetic field distributions in the near-field region of the antenna with the perimeter of the interrogation zone up to 2.8 times of operating wavelength. The proposed antenna is promising for UHF near-field RFID reader applications.

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